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Technical Report No. 1

SEISMIC AFTERSHOCK INVESTIGATIONS – PROJECT VELA PORTLAND, OREGON, EARTHQUAKE OF 6 NOVEMBER 1962

Prepared for:

Air Force Technical Applications Center
Washington 25, D. C.

Under Contract No. AF 49(638)-1205

STANFORD RESEARCH INSTITUTE
MENLO PARK, CALIFORNIA

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SRI Project No. PHU-4322

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INTRODUCTION

Project VELA is an extensive research program being conducted by the Advanced Research Projects Agency with the objective of developing effective and reliable techniques that may be useful in monitoring an international agreement to ban the testing of nuclear weapons. One proposed method of detecting and locating the source of a clandestine underground explosion is the monitoring of post-event seismic noises (aftershocks) produced by the primary event. The basic premise of post-event seismic monitoring is that aftershocks from earthquakes and underground explosions have different characteristics. As part of Project VELA, Stanford Research Institute (SRI) has undertaken a program of monitoring post-event seismic disturbances following both earthquakes and underground nuclear explosions to establish or deny the validity of this premise. The specific objectives are:

(1) to determine the characteristics of earthquake- and explosion-induced aftershock sequences

(2) to study the relationship of the foci of earthquake aftershocks to the focus of the primary earthquake

(3) to improve methods of data analysis and interpretation of the results of aftershock monitoring.

This is a report of the aftershock monitoring operations following the magnitude 4.75 earthquake in Portland, Oregon, on 6 November 1962. It includes times of occurrence of observed aftershocks, general geology of the area, and procedures used. Detailed analysis of the data in relation to the project objectives will be presented in a final summary report.

SEISMIC EVENT AND OPERATIONS

The Portland earthquake occurred at 03:36:46.9 GCT on 6 November 1962. The magnitude assigned to this earthquake by Berkeley is 4.75.

Preliminary epicenter estimates based on limited data placed this earthquake south of Portland near Oregon City. A more exact later determination made by Oregon State University on the basis of data from stations in Washington, Oregon, Nevada, and California placed the epicenter of this earthquake at approximately 45.5° N 122.7° W near the center of downtown Portland. Preliminary calculation by the U. S. Coast and Geodetic Survey places the epicenter (Card No.92-62) at 45.8° N 122.5° W.

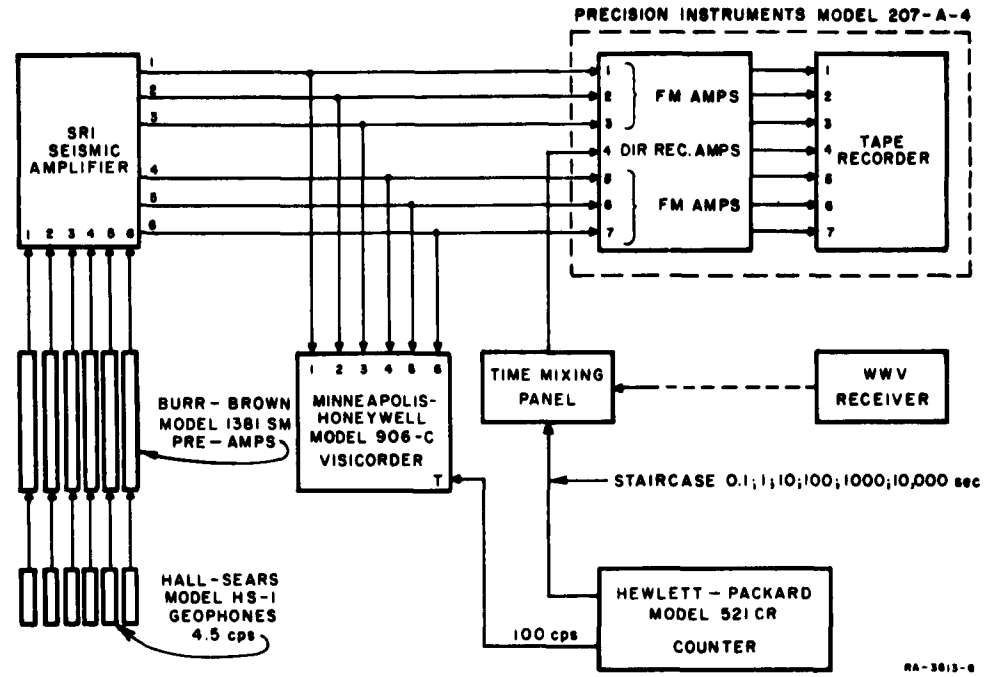
Structural damage from the Portland earthquake was minor despite its occurrence in the midst of an area of heavy population density. The U.S. Coast and Geodetic Survey has assigned a maximum felt intensity of VI in Portland to this earthquake. A few bricks in poorly constructed chimneys were dislodged and plaster walls cracked. The Coast and Geodetic Survey's strong motion seismograph in Portland recorded a maximum vertical acceleration of 0.076g from this shock, with horizontal accelerations of 0.103g and 0.96g.

No terrain effects such as landslides, displaced boulders, or surface cracks were either observed or reported in the epicentral area.

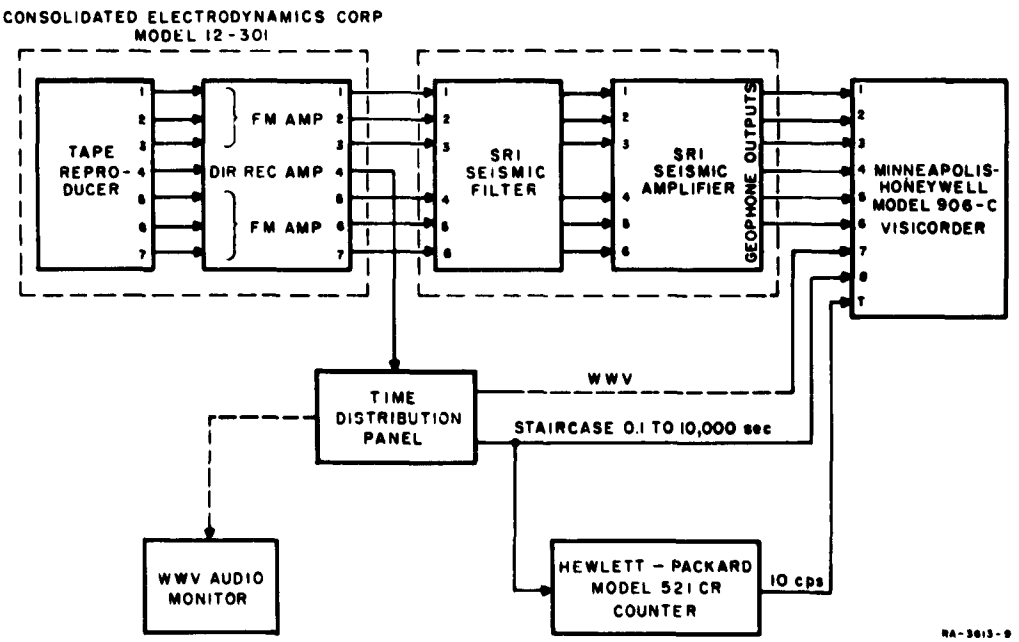
Three portable seismographs were used in the Portland earthquake aftershock investigation. Each consists of an array of six 4.5-cps seismometers recording on a magnetic tape with appropriate timing signals. Block diagrams of the recording and playback instrumentation are given in Figure 1. These seismographs were located as shown in Figure 2 and tabulated in Table I.

TABLE I SEISMOGRAPH LOCATIONS

Station	Location					Distance from the Earthquake Epicenter (km)
	T.	R.	Sec.	Lat. (N)	Long. (W)	
A_1-Redland	3S	3E	18	45° 18' 45"	122° 28' 48"	27.8
A_2-Clark Hill	1S	2W	35	45° 26' 36"	122° 54' 16"	19.8
B_1-Carus	3S	2E	29	45° 17' 18"	122° 35' 15"	27.3
C_1-Skyline	2N	1W	32	45° 37' 07"	122° 50' 24"	17.7
C_2-Solberger	2N	2W	21	45° 38' 37"	122° 56' 48"	25.2



(a) RECORDING INSTRUMENTATION



(b) PLAYBACK INSTRUMENTATION

FIG. 1 BLOCK DIAGRAMS OF SEISMOGRAPH INSTRUMENTATION

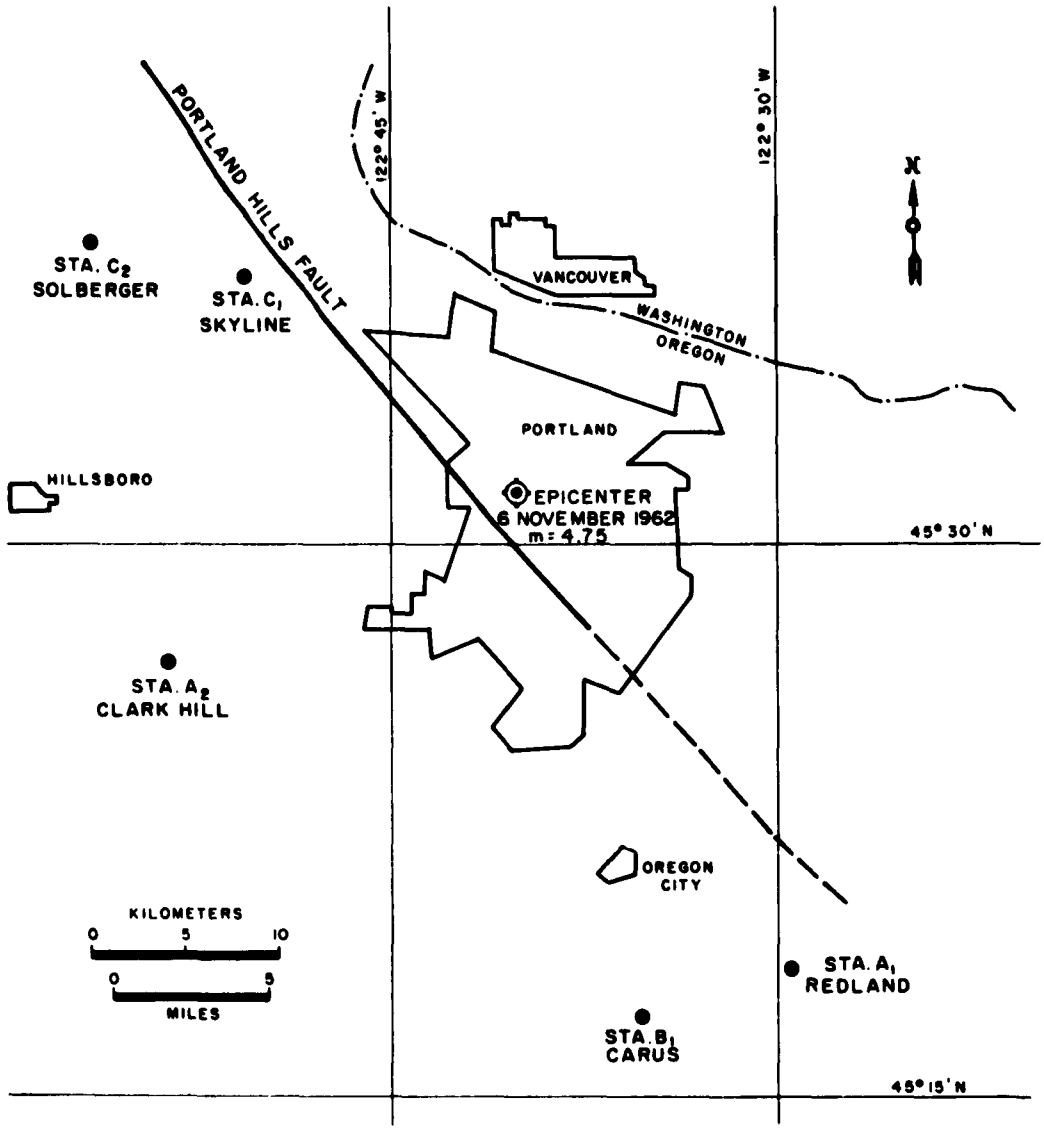


FIG. 2 SEISMOGRAPH STATION LOCATIONS

The distances between the seismographs and the epicenter of the primary earthquake were in general greater than those used in previous aftershock investigations,* but because of the heavy concentration of population in the Portland metropolitan area it was not possible to locate suitable recording sites closer to the primary epicenter.

Figure 3a and Table II show the operating times of the different seismograph stations Recording began 88.2 hours (3.7 days) after the primary earthquake and continued at one or more stations for 404.9 hours. From time to time one or two stations were not in operation because of moves from one site to another, necessary instrument maintenance, or power failures.

TABLE II SEISMOGRAPH OPERATING TIMES

Station	Recording Begun			Recording Ended		
	Date (1962)	Time (GCT)	Hours from Primary Earthquake	Date (1962)	Time (GCT)	Hours from Primary Earthquake
A_1-Redland	9 Nov	20:20	88.7	11 Nov	15:59	132.4
A_2-Clark Hill	12 Nov	00:55	141.3	26 Nov	16:41	493.1
B_1-Carus	9 Nov	19:50	88.2	25 Nov	15:38	468.0
C_1-Skyline	11 Nov	21:15	137.6	13 Nov	20:58	185.3
C_2-Solberger	14 Nov	01:00	189.4	26 Nov	06:09	482.5

GEOLOGY AND SEISMICITY OF THE EPICENTRAL AREA

The predominant geological feature of the Portland region is the essentially flat-lying thick Miocene Columbia River basaltic flow overlying an older Tertiary sequence of marine sediments. Overlying a portion of the Columbia River basalt is a thin sequence of Plio-Pleistocene Boring basalt flows interspersed with continental sediments. The principal structural feature of the region is the Hillsboro Basin to the west of Portland filled with several hundred to thousands of meters of Pleis-

*W. H. Westphal; "Project San Andreas Aftershock Recording"; Final Report; Contract No. AF 49(638)-1071, SRI Project No. PHU-3628, June 30, 1962; Stanford Research Institute, Menlo Park, California; Unclassified.

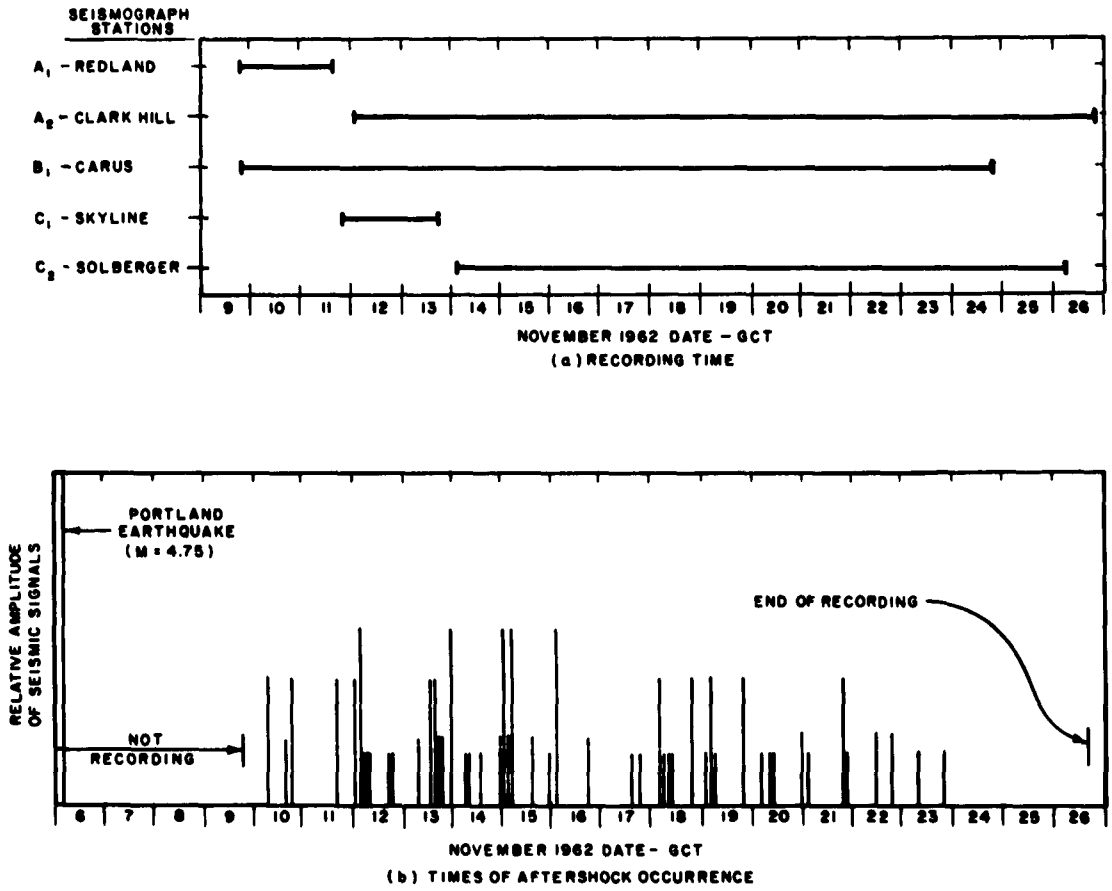


FIG. 3 TIMES OF RECORDING AND OF AFTERSHOCK OCCURRENCE

tocene gravels. The Columbia River basalt which presumably underlies this structural basin rises up to the north and east to form the Portland Hills immediately west of the city. The gentle southwestward dip of these basalts out of the Hillsboro Basin changes at the crest of the Portland Hills to a moderately steep northeastward dip terminated by a 40 meter to 200 meter high escarpment along the Willamette River. This escarpment has been interpreted as an asymetrical anticline with a steeply dipping northeast limb with or without an associated parallel fault. From the position of the epicenter of the 6 November earthquake and preliminary determination of later aftershock epicenters it seems evident that this escarpment marks the location of an active fault trending northwest-southeast from at least Scappose Creek to the center of Portland, a distance of about 30 to 35 km.

All the seismograph station sites were southeast of the Portland Hills escarpment (see Figure 2). The Redland and Carus stations were on the Boring basalt about 7 and 13 km respectively southwest of an extension of this escarpment southeast of Portland. The Skyline and Solberger stations were on the Columbia River basalt 1.5 and 6 km respectively southeast of the northwest end of the escarpment. The Clark Hill site was on a knob of Columbia River basalt on the southeast side of the Hillsboro Basin about 17 km southwest of the escarpment.

The 6 November earthquake was the first significant damaging earthquake in the Portland area since 15 December 1953 when an earthquake with a maximum felt intensity of VI occurred in the same general area. Two smaller earthquakes on 17 September and 7 November 1961 had epicenters close to the 6 November 1962 epicenter. Other smaller earthquakes in the Portland area have been reported in 1954, 1957, 1958, and 1959. On a basis of the calculated epicenters and isoseismic maps it seems likely that all these earthquakes except for one on 16 November 1957 originated close to the Portland Hills escarpment.

RESULTS

Condensed time records were made by reproducing the magnetic tapes 32 times faster than they were originally recorded on an oscillograph

with a paper speed of 0.2 in./sec. On these records 50 small earthquakes were recognized. On the basis of S-P times of less than 15 sec all these 50 small earthquakes were determined to be local in origin and are considered to be aftershocks of the 6 November earthquake. The times of arrival to within the nearest 10 sec and estimated relative signal amplitudes on the seismic records are listed in Table III and plotted in Figure 3.

Of these 50 earthquakes 16 were recorded at three stations, 10 at only two stations, and 24 at only one station. Some of the earthquakes were observed on less than three stations because (1) one or two stations were out of operation at the time or (2) the earthquakes had insufficient magnitude to produce recognizable signals at stations more distant from their origin. Thirteen earthquakes were recorded with weak signals only at the Skyline (C_1) or Solberger (C_2) stations. These were the two locations closest to the Portland Hills escarpment, and the recording of events only at these stations supports the theory that the events originated near the escarpment. Two earthquakes, Events 12 and 39, were recorded only at the Carus station(B_1)while at least one of the other two stations was in operation. These two events, near Oregon City, probably were on a southeastern extension of the fault associated with the Portland Hills Escarpment.

The apparent increase in aftershock activity on 12 November (see Figure 3) reflects the commencement of recording at the Clark Hill Station (A_2) and the Skyline Station (C_1). These two stations were closer to the reported epicenter of the primary earthquake. Hence they were capable of recording smaller magnitude aftershocks not detectable at the Redland (A_1) and Carus (B_1) stations 10 km further from the primary epicenter.

Aftershock activity diminished toward the end of the monitoring period with no aftershocks observed in the last 70 hours of recording. The last observed aftershock (Event 50) occurred at 18:47:50 (GCT) on 23 November, 423 hours or 17.6 days after the primary earthquake.

TABLE III

RECORDED AFTERSHOCKS

Event No.	Date	Arrival Time (GCT)	Estimated Amplitude	Event Recorded		
				Station A_1	Station B_1	Station C_1
1	10 Nov	06:51:10	strong	x	x	off
2		14:10:00	moderate		x	off
3		19:48:30	strong	x	x	off
4	11 Nov	15:27:40	strong	x	x	off
5	12 Nov	00:08:00	strong		x	x
				Station A_2		
6		01:34:25	very strong	x	x	x
7		03:50:30	weak			x
8		04:09:20	weak			x
9		05:38:40	weak			x
10		16:05:20	weak			x
11		17:07:50	weak	x		x
12	13 Nov	08:15:40	moderate		x	
13		12:34:25	strong		x	x
14		15:51:35	strong	off		x
15		16:58:35	moderate	off		x
16		20:33:10	moderate		x	
						Station C_2
17		23:28:42	very strong	x	x	
18	14 Nov	04:25:30	weak			
19		08:15:50	weak	x		
20		12:07:40	weak	x		
21		23:52:50	moderate	x	x	x
22	15 Nov	01:39:15	very strong	x	x	x
23		01:43:00	moderate	x	x	x
24		03:56:30	very strong	x	x	x
25		12:48:15	moderate	x	x	x
26		23:31:30	weak	x	x	x
27	16 Nov	00:24:25	very strong	x	x	x
28		15:44:00	moderate	x	x	x
29	17 Nov	13:29:20	weak			x
30		20:43:05	weak		x	

TABLE III CONTD.

Event No.	Date	Arrival Time (GCT)	Estimated Amplitude	Event Recorded		
				Station A_1	Station B_1	Station C_1
31	18 Nov	02:01:20	strong	x	x	x
32		05:39:30	weak			x
33		09:54:51	weak			x
34		10:25:40	weak			x
35		18:02:21	strong	x	x	x
36	19 Nov	00:31:26	weak			x
37		03:46:10	strong	x	x	x
38		05:27:02	weak			x
39		16:53:50	strong		x	
40	20 Nov	02:50:13	weak	x	x	x
41		07:51:00	weak	x		x
42		09:13:40	weak			x
43		23:58:30	moderate	x	x	x
44	21 Nov	01:29:00	weak			x
45		18:19:00	strong		x	x
46		18:50:40	weak	x		
47	22 Nov	11:38:30	moderate	x	x	x
48		15:50:10	moderate	x		x
49	23 Nov	05:58:30	weak			x
50		18:47:50	weak	x	x	x

PROJECT PERSONNEL

Field operations and data analysis were conducted by W. H. Westphal, project leader, A. L. Lange, T. J. Cameron, and L. C. Harlen.

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